# Improving an Incomplete Road Network given a Budget Constraint

Corrinne Luteyn
KU Leuven, Leuven Mobility Research Center - CIB
e-mail: corrinne.luteyn@kuleuven.be

Pieter Vansteenwegen
KU Leuven, Leuven Mobility Research Center - CIB

In this research, we look for savings that can be obtained when a (public) transport company or a logistic player has the ability to discuss road network improvements with the traffic manager. We assume that there is a fixed budget available to improve a road network. Within this given budget, the logistic player can suggest a set of adjustments in the network to the traffic manager. In this research, three different improvements are considered. The first improvement is (re-)opening an existing road that was currently closed for the vehicles of the logistic player. This existing road might be for example a pedestrian street which will be (re-)opened for the logistic player. Another possibility is to widen a road between two locations, while the third possibility is the transformation of a road into a one-way street with a higher speed.

The main goal of this research is to develop a procedure to find the best set of improvements in an existing road network, which minimizes the total travel time of the vehicles of the logistic player in the network. The construction of routes for the vehicles of the logistic player can be seen as variant of the Vehicle Routing Problem (VRP). In this variant, the considered network is incomplete, which means that a direct path is not always available between each pair of locations. Furthermore, only a selection of the known customers has a positive demand and should be served by a vehicle. This variant is called the Steiner Vehicle Routing Problem (SVRP) and is introduced in [1]. Note that in the SVRP, only the routing of the customers is considered, which means that the determination of the best set of improvements is not included. In order to determine the best set improvements of a road network, we introduce the Steiner Vehicle Routing Problem with a Budget Constraint (SVRPBC). Since the group of known customers with a positive demand varies from day to day, this best set of improvements is determined over a set of days. Based on the mathematical formulation for the SVRP, presented in [1], we introduce a Mixed Integer Programming formulation for the SVRPBC.

To solve the SVRPBC for instances of realistic size, we present two different heuristics. The first heuristic is an extension of the Two-Phase Heuristic to determine the best single improvement of an incomplete road network, presented in [1]. This Extended Two-Phase Heuristic (ETPH) consists of the same two phases as the Two-Phase Heuristic, the construction phase and the analysis phase.

During the construction phase, routes for the vehicles in the original network are constructed using a Variable Neighborhood Search (VNS). The applied VNS is presented in [1]. In the second phase of the ETPH, the constructed routes are analyzed to estimate the benefits of all possible combinations of improvements within the given budget. The benefit of a set of improvements is estimated to be equal to the sum of the benefits of the single improvements in that combination. In contrast to the Two-Phase Heuristic, the ETPH is extended with a testing stage. This testing stage is necessary, since the improvements of a set can interfere with each other. The realized total benefit of the set can be larger or smaller than the sum of the benefits of the single improvements due to this interference. This ETPH requires that all possible combinations of improvements within the given budget are determined. Since this is time and memory consuming, we present a second heuristic to solve the SVRPBC.

The second heuristic is an Adaptive Large Neighborhood Search (ALNS) [2]. This ALNS has a main structure based on a Simulated Annealing (SA) algorithm, where the next solution is generated by a large neighborhood. This large neighborhood consists of a set of destroy and a set of repair methods. These destroy and repair methods are unique for this problem, since in this case, the best combination of improvements should be determined instead of the best routes for the vehicles. After the generation of a new solution, the costs of this solution is determined by a VNS.

To test of the performance of both heuristics, we used 16 of the benchmark instances which are presented in [1]. All these benchmark instances are based on a symmetric incomplete road network of 150 possible customers and a depot. The number of customers in these 16 instances is equal to 20 to 51, while the number of vehicles ranges from 1 to 4. Preliminary tests on these benchmark instances show that by improving the network, the total travel time of the vehicles in the modified network can be decreased by on average 5 %. Furthermore, we can conclude that both heuristics have the same performance, while the ALNS is faster, since the determination of all possible combinations within the given budget is not required. The 16 larger benchmark instances of [1] can only be solved by the ALNS, due to the required determination of all possible combinations in the ETPH. The decrease in total travel time is in these larger instances on average smaller than in the first 16 instances.

## Acknowledgment

This research was funded by a Ph.D. grant of the Agency for Innovation by Science and Technology in Flanders (IWT).

## References

[1] C. Luteyn, Reginald Dewil and Pieter Vansteenwegen. Determining the Best Network Change for Vehicle Routing Problems in an Incomplete Network. *Submitted to European Journal of Operational Research*, 2016.

[2] S. Ropke and D. Pisinger. An adaptive large neighborhood search heuristic for the pickup and delivery problem with time windows. *Transportation science*, 40(4):455–472, 2006.